ALBERTA ASPEN

Tomorrow's Resource Today

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Prepared by
Wilfred A. Côté
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The Forest Products and Forest Industrial Development Research Program
for
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ALBERTA ASPEN is a ready resource and one of the Province's most valuable assets. Yet, compared with Alberta's petroleum and natural gas resources, it remains relatively unknown and unappreciated. Obviously the events of the past decade have created greater interest in fossil fuels than in a renewable resource, wood. This reaction to world events fails to consider the fact that anything that can be synthesized from oil, gas or coal can also be synthesized from wood without depleting fossil hydrocarbons which are not unlimited.

Wood, effectively utilized, can make a very significant economic impact on Alberta for decades into the future because the forests can be managed on a sustained yield basis without jeopardizing this resource for future generations. More than half of the total area (644,000 square kilometers) of the Province is classified as forest land. This amounts to nearly 400,000 square kilometers with approximately 1.5 billion cubic meters of growing stock, according to estimates by forest management specialists. About 26 million cubic meters could be cut annually without threatening the productivity of the resource. However, in recent years slightly over half of the annual allowable cut of softwood has been harvested while less than 6% of the hardwood is being utilized.

These figures take on a more dramatic perspective when it is realized that deciduous forests make up 40% of Alberta's forests, yet such a small amount of hardwood is harvested each year. The coniferous forest of spruce, fir and pine which constitutes 60% of the Province's forests could be utilized to a much greater degree as well, but considerations such as accessibility are contributing factors. The case for much greater utilization of Alberta Aspen is much more compelling because trembling aspen is the principal species of the hardwood type and this widely distributed tree accounts for the largest volume of growing stock among the hardwoods in the Province. Since it is available in such abundance, why is it not used in place of species that are less abundant?

Why Not Aspen?

Generally a number of economic factors influence the utilization of a material: amount available, accessibility, distance from processing plant, distance to market, quality compared with competing materials, and of course the initial purchase price and cost of harvesting. These

apply to aspen as they do to any raw material. In the past, perhaps the perception of inferior quality of aspen wood was the reason for its limited utilization. Today, much more is known about the diseases that attack forest trees, the relationship between age of the trees and severity of attack, the chemical constituents of wood that may be degraded by attack, and the kinds of products that can be extracted from a tree that contains some degrade.

In this publication you will find graphic evidence of the effects of one particular disease, *Fomes igniarius*, on quaking aspen. This is a white rot type of fungal disease that is particularly prevalent in overmature trees. You will note that even when an aspen tree has reached an "advanced" state of decay, there is much wood substance remaining. While it might not be used in its entirety for lumber, flakes or other forms of wood, a number of other uses for this biomass are available. Oriented strand board, low density fiberboard, and pulp are proving to be good possibilities.

The Wood of Aspen

Trembling aspen (*Populus tremuloides* Michx.) produces a wood that is white to creamy in color in the sapwood region, becoming light gray or light brown in the heartwood. Although classed as a hardwood (deciduous species), aspen wood is relatively soft. It is straight-grained and medium to light in weight (specific gravity 0.35 to 0.40, approx.). The wood has a silky luster and takes a good finish. When properly seasoned it has good machining properties. In the states of Minnesota and Michigan, where poplar utilization has grown to a high level because of abundant supplies of this species, a great variety of products has been manufactured for some time. Similar utilization should be possible in Alberta, subject to somewhat different local conditions in the marketplace. Aspen is used for dimension stock, lumber, plywood, pallets, box manufacturing, crates, waferboard and oriented strandboard production, pulp and paper and many other specialty applications. If treated with appropriate preservative chemicals, aspen can be utilized in exposed exterior construction.

The Cellular Structure of Aspen Wood

The illustrations in this publication provide graphic evidence that the wood of aspen is well suited, structurally, for the wide range of applications in which it is currently used. It is a porous wood, but the pores are relatively small in diameter when compared with woods such as the oaks. Examination of the scanning electron micrographs of small cubes of aspen reveals that the larger pores result from the presence of vessels which are long tubular structures assembled from individual cells. These vessels are surrounded by fibers having somewhat thicker walls than the vessel elements.

At the end of each growing season a row of terminal parenchyma cells is produced which helps to delineate the annual rings or growth increments. This same type of cell is also found in rays, narrow bands of tissue which

are oriented radially from the center of the tree toward the bark. Parenchyma cells are thin-walled storage cells. They are short and brick-shaped.

The outer part of the tree stem is sapwood. Although the color difference is not as striking in aspen as in some species, heartwood is produced in this species and is located inside of the sapwood. Many of the vessels which are open for longitudinal conduction of fluids become blocked by tyloses with the formation of heartwood. Tyloses are thin, membranous structures that proliferate from the neighboring parenchyma cells into the vessel cavities. Their presence in the vessels reduces the penetrability of the aspen by liquids in processing, such as pulping or wood preservation treatment.

When aspen wood is pulped, removal of the lignin frees the individual cells from each other. Then the vessel elements, the fibers and the parenchyma cells can be compared for size, shape and anatomical features. For example, the small openings or pits in the cell walls that provide for fluid movement laterally from cell to cell are readily observed with the aid of a microscope.

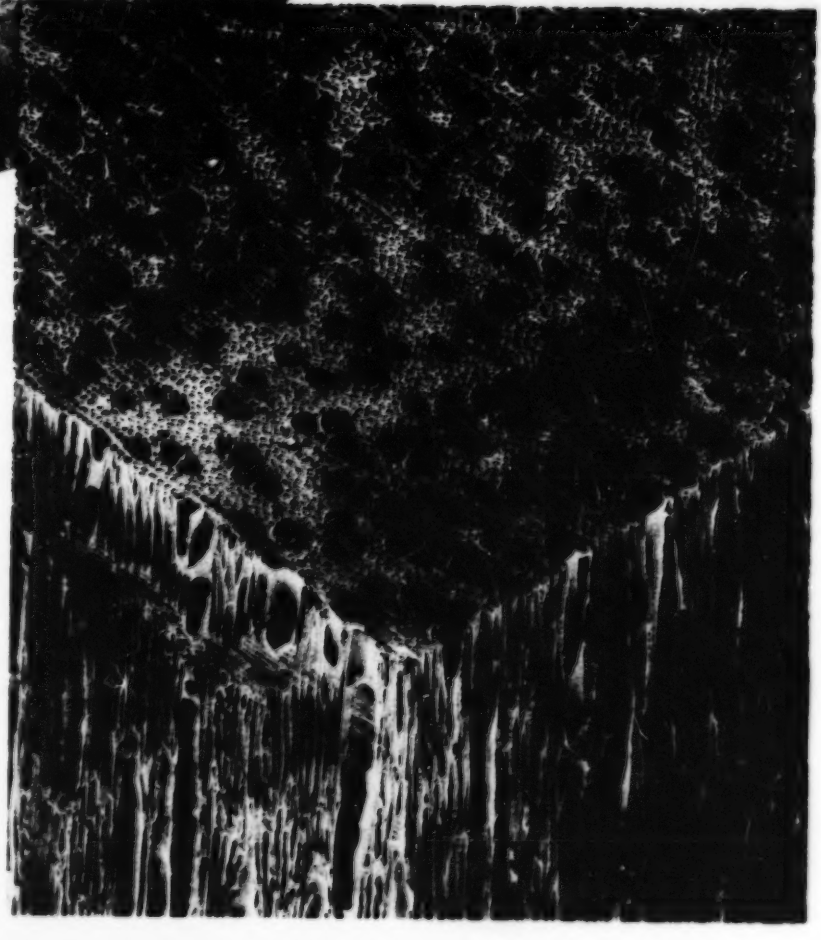
In the pages that follow, many photomicrographs and scanning electron micrographs have been used to illustrate the important features that help to determine the various end uses of this important aspen wood. Photomicrographs are made with a light microscope and a camera attachment. Scanning electron micrographs require the use of a microscope that utilizes an electron beam for illumination and recording. In many respects it resembles a television picture tube that has been specially adapted to produce a high resolution, three-dimensional image. The individual figure captions should be helpful in the interpretation of the details of each photograph.

The Wood Quality Study

Many of the photographs that follow in this publication were produced during a study of the quality of aspen sponsored by the Alberta Research Council. The principal goal was to determine the condition and the quality of wood substance found in each of four categories of aspen logs. Disks of each category were collected by W. R. Dempster and Associates, Ltd., Consulting Foresters, and were coded according to the definitions included in their December, 1982 report subtitled "Wood Procurement."

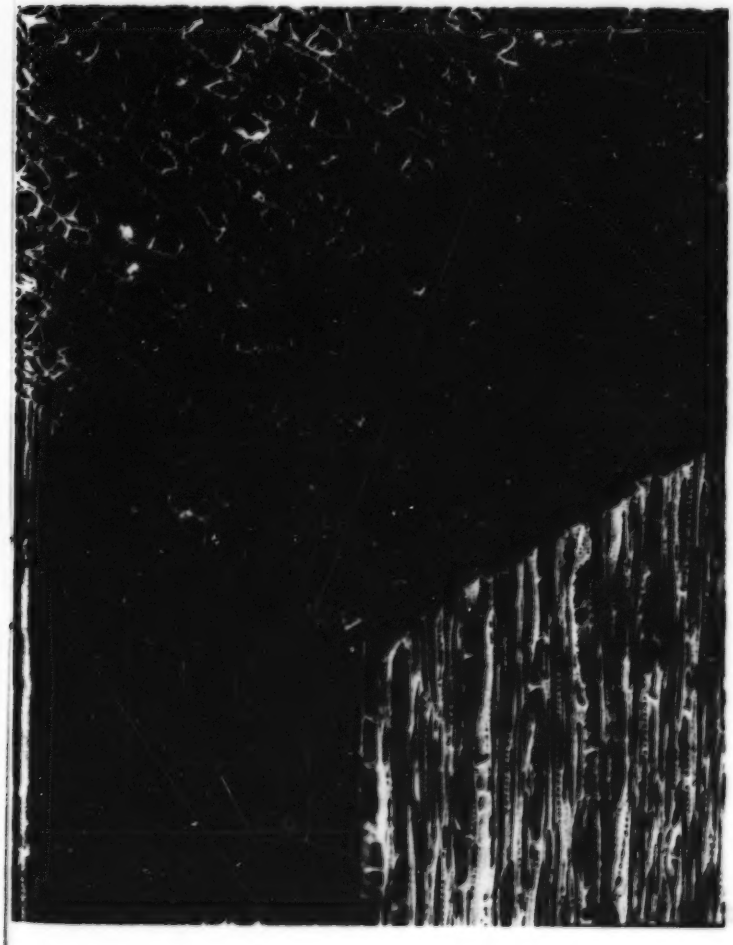
Accordingly, the coded disks were photographed before samples were removed for photomicrography and scanning electron microscopy. The four categories are "clear," "stained," "intermediate" and "advanced decay." Representative micrographs from the sapwood and heartwood regions of each disk are included to demonstrate graphically the relationship of the category with the physical condition of the woody material as viewed at the microscopic level. The intention was to give the potential user of aspen an opportunity to judge the significance of this classification scheme for production applications.

This disk of aspen is in the "clear" category which indicates that there is no evidence of decay. Aspen wood of this quality may be used for any of the wide range of products described earlier.

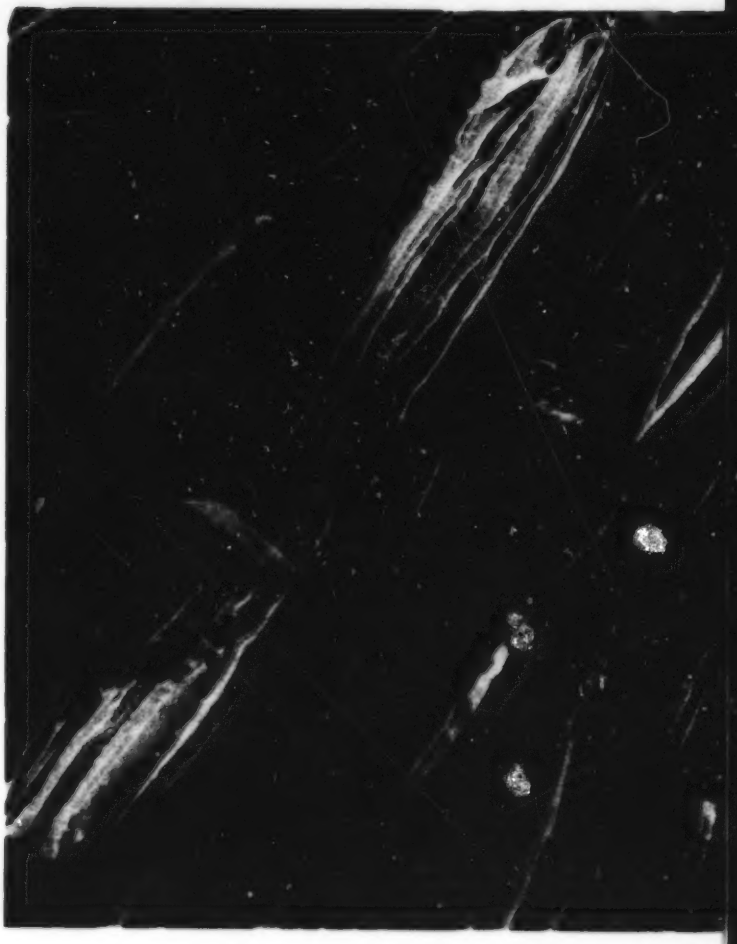


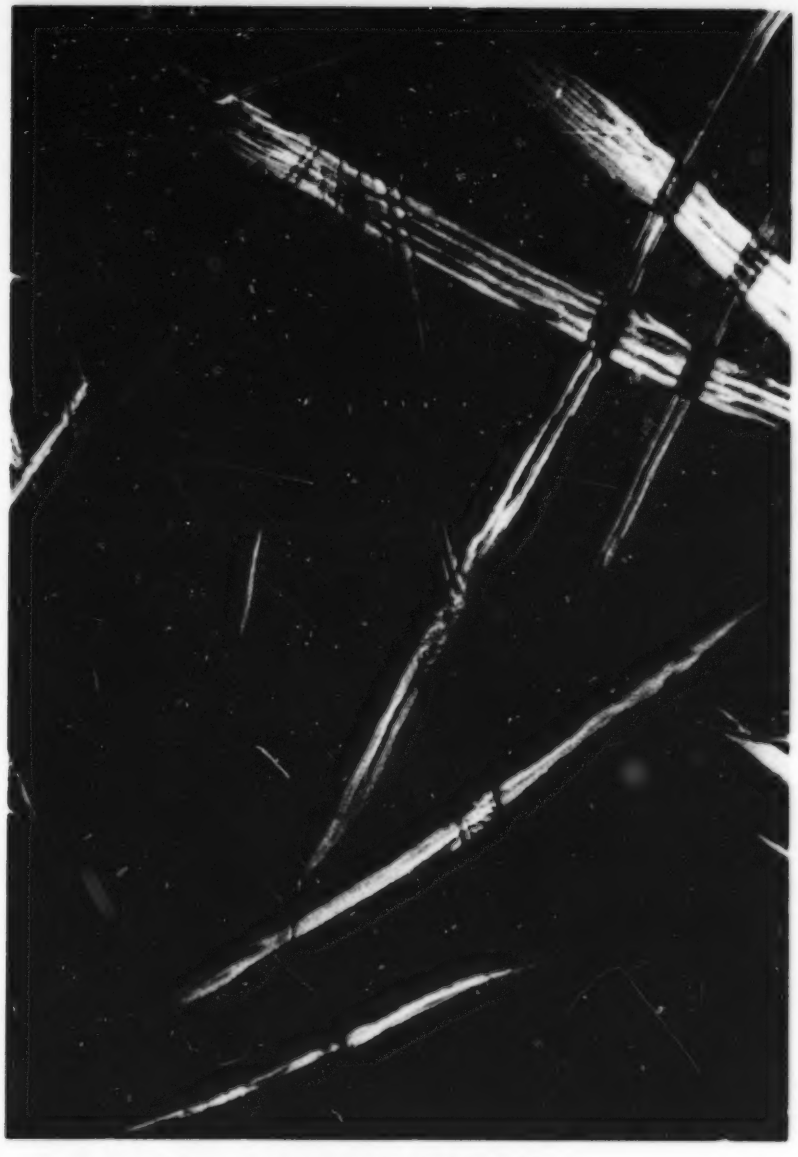
The scanning electron microscope was used to produce this micrograph of a small cube of aspen from the sapwood region of Disk 6-8-C. The three aspects of wood, the transverse or cross-section, the radial and the tangential surfaces can all be viewed at one time by utilizing this technique. Portions of two annual increments are included in the cube. Magnification: 85X.

In this micrograph, a small cube of aspen wood from the heartwood region of Disk 6-8-C was used for comparison with the sapwood. Note that the only visible change is that the vessels in this heartwood contain membranous structures called tyloses. They can be seen on the transverse surface as well as on the radial and tangential views. Magnification: 70X.



A small piece of aspen sapwood from Disk 6-8-C was macerated (pulped) to remove the lignin. This process frees one wood cell from another in the production of pulp for paper manufacturing. In this instance the cells were left undisturbed to illustrate the relative sizes and positions of these elements in the wood. Scanning electron micrograph, magnification: 260X.





The light microscope and polarized bright field technique were employed to prepare this photomicrograph of an array of aspen wood cells: vessel elements, fibers and ray parenchyma cells from a macerated sample taken from the sapwood region of Disk 6-8-C. The fibers are slender and long with relatively thick walls. The vessel elements are larger in diameter and their walls are heavily pitted. The small rectangular-shaped cells are parenchyma. Magnification: 110X.

Aspen wood in the "stained" category contains regions of early or incipient decay generally in the heartwood area. The wood is discolored in this central core, but one finds no evidence of deterioration at the microscopic level as can be noted in the scanning electron micrographs that follow. There may be a slight reduction in the specific gravity of this wood which could be reflected in some loss of mechanical strength. In this particular disk, 6-3-S, three branches (knots) add to the coloration as well. Only applications requiring clear, white wood would specify rejection of the heartwood portions of such a log.

In this scanning electron micrograph of a small cube from the sapwood of Disk 6-3-S, the wood structure appears to be the same as that found in the "clear" sample. Magnification: 85X.

The heartwood of Disk 6-3-S, when viewed at this level of magnification, appears similar to the heartwood in "clear" specimens. Magnification: 85X.

When this wood structure is observed at a much higher magnification such as in this transverse view of stained heartwood at 1200X, decay fungi should be readily observed if present. Here the relative cell wall thickness of the fibers surrounding the large-lumened vessels in the center can be seen. Note how the tyloses fill the vessels thus restricting longitudinal flow through the wood.

Disk 6-3-S provided this sample from the sapwood region. At this magnification of 1800X the details of fiber walls can be examined. In aspen, fibers may contain a so-called "gelatinous layer" which is actually unlignified pure cellulose. This layer is only loosely attached to the inside of the fiber wall and can be readily displaced by cutting with a sharp knife. In many hardwoods these gelatinous fibers occur only in leaning trees, but in aspen they are found in normal, straight and erect trees.

Normal fibers in aspen lack the gelatinous layer. These cells have small lumens and relatively thick walls. Small pits occurring in pairs provide for lateral conduction from fiber to fiber. Fibers are specialized for support and strength while vessel elements provide longitudinal conduction of sap. Magnification: 1800X.

As evident from this scanning electron micrograph, the sapwood of aspen in the intermediate category remains sound. This cube was taken from Disk 4-9-I and the micrograph magnification is 70X.

Aspen wood of the "intermediate" category is represented by this disk, 4-9-I. Much of the wood remains firm, but the discoloration and general appearance of the material in the heartwood region suggests that decay has advanced beyond that found in the "stained" category. Note that the sapwood appears to remain sound and clear. The specific gravity of the degraded wood is generally reduced somewhat from the clear and stained levels. Toughness is one mechanical property that is particularly susceptible to reduction at this stage.

This cube of heartwood from Disk 4-9-I provides the first signs of deterioration in this series of studies. There is a "punky" appearance which suggests that the woody tissue is less firm and resistant to cutting. The cell walls no longer cut cleanly and there are many frayed membranes due to the depolymerization of the chemical constituents of wood by decay enzymes. Magnification: 80X.

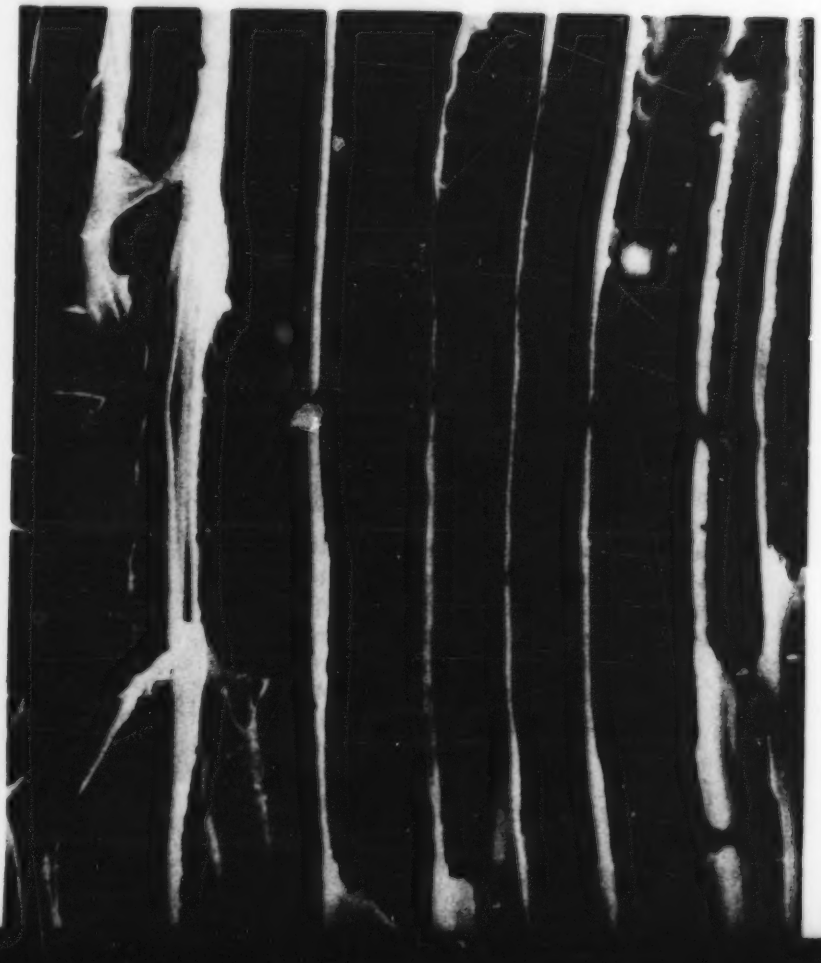
Scanning electron micrograph of the radial surface of a sample from the heartwood region of Disk 4-9-I. This perspective offers a view of the inside of vessels which contain the membranous tyloses. The pitting between vessels as well as between ray parenchyma and vessels is exposed also. A few of the narrow-lumened fibers, some containing crystalline deposits, are resolved at this magnification of 270X.

Although the sapwood of samples of aspen in the "intermediate" category do not show evidence of fungal hyphae at low magnification in scanning electron micrographs, other techniques should be tried. This is a photomicrograph taken with the light microscope and bright field illumination. The specimen was a thin radial section of the wood, stained to enhance contrast and recorded on color film. The magnification is 400X. The band of ray parenchyma cells traversing the center of the photograph contains darkly stained fungal hyphae which appear to be largely concentrated in this type of tissue. As decay progresses, the fungus will move to longitudinal tissue as can be observed in the upper right portion of the photomicrograph.

In aspen of the "advanced decay" category the discoloration may extend beyond what would normally be classed as heartwood. Internal to this discolored zone the wood may appear soft and punky with one or more dark bands called "black zones" outlined in a discontinuous pattern. These dark bands represent concentrations of breakdown products from the metabolism of the wood substance by the fungus, *Fomes igniarius*.

This scanning electron micrograph was prepared from a sapwood sample taken outside of the discolored zone in Disk 1-5-A. It illustrates that a large volume of wood remains sound even though decay has proceeded in the core of the tree. At this level of magnification, 80X, it appears very similar to the sapwood of the clear category.

Scanning electron micrograph of a small cube of aspen wood taken from the decay zone of Disk 1-5-A. The wood substance does not appear to have deteriorated much beyond that from the "intermediate" category. However, on the radial and tangential surfaces many of the vessels and fibers contain some of the breakdown products of the decay process. In addition to these deposits, large quantities of crystalline materials appear to concentrate in or near the black zones. Magnification: 80X.

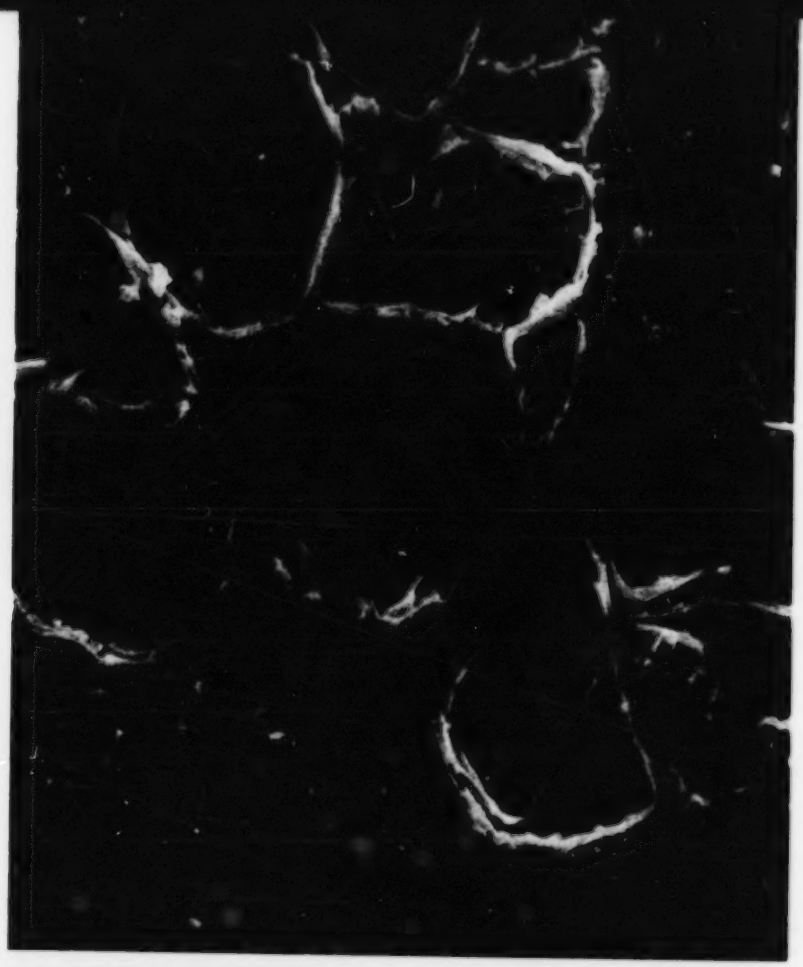


At higher magnification (600X) degradation of the cell walls and the bore holes formed by the fungal hyphae are evident. A few hyphae can be seen in the fiber lumens at the right.

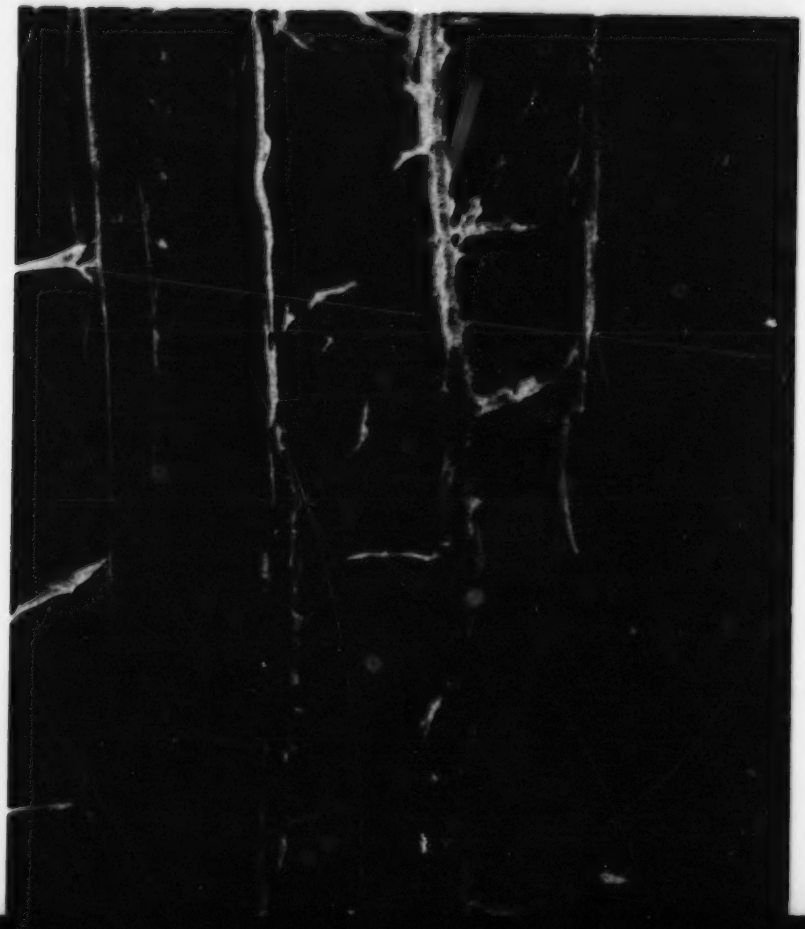
This cross-section of aspen wood was taken from the stained portion of Disk 1-5-A, but it is obvious that decay has proceeded in localized areas. Small amounts of crystalline deposit and a few hyphae can be seen. The walls of four cells have been partially degraded. Magnification: 1200X.

In another cross-section of stained heartwood from Disk 1-5-A the tyloses have been attacked by the fungus and the cell walls exhibit some deterioration. One cell is filled with crystalline deposits which suggests that some active decay has proceeded nearby. Fungal hyphae can be observed in many of the cells. Magnification: 1200X.

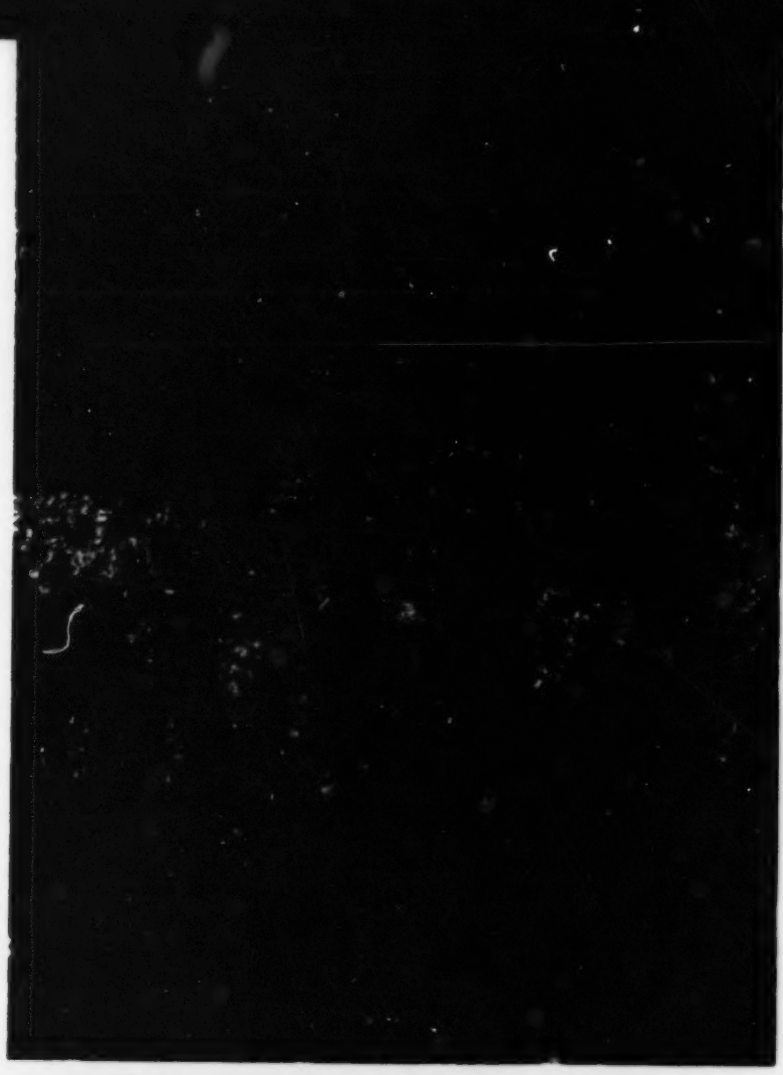
In areas of advanced decay such as in Disk 1-5-A, one or more "black zones" may appear. When examined with the aid of a light microscope the zone looks like this photomicrograph of the cross-section of such an area. Many cell lumens are filled with the breakdown products of the decay process including some of the crystalline deposits shown in scanning electron micrographs that follow. Fungal hyphae can be seen in the vessels. The section was stained to enhance contrast in the normal cell walls. Magnification: 240X.



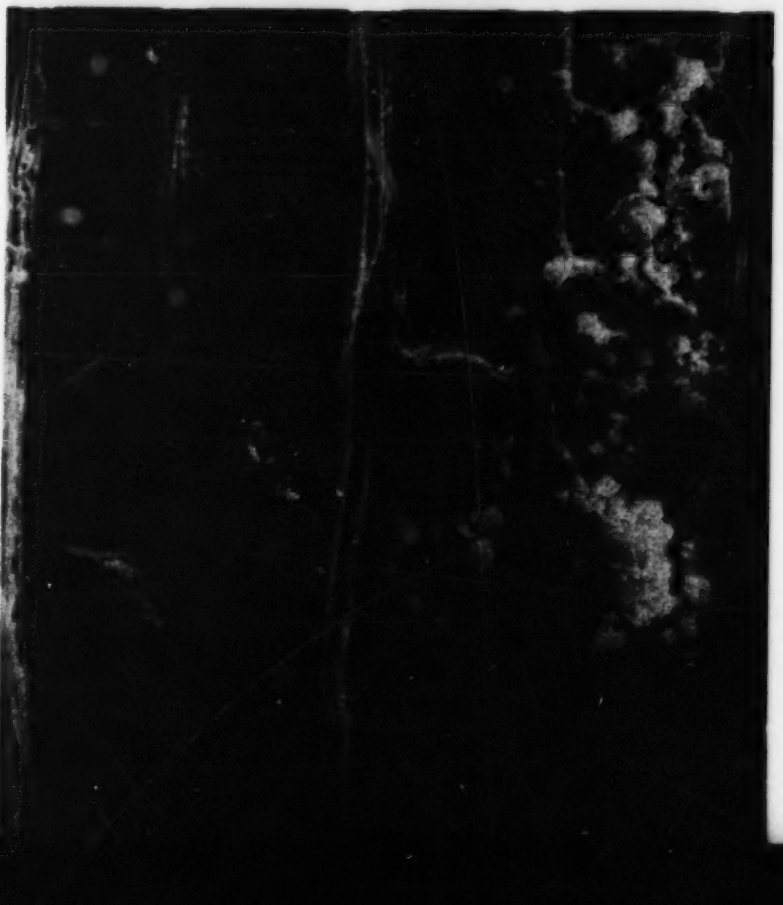
Transverse view of heavily attacked heartwood of aspen from Disk 1-5-A which illustrates that even in such an advanced state of decay much wood substance remains. The fungal hyphae are abundant in the vessel lumens where the tyloses have been severely degraded. Clusters of crystalline deposits occur in fibers and vessels. Magnification: 750X.



Longitudinal view of similar area to that in accompanying photograph. Although the vessels (center) appear to contain most of the hyphae, careful study of fibers and parenchyma cells reveals that they are not immune from attack. Magnification: 450X.



In or near the black zones in aspen wood that has been attacked by *Fomes igniarius* there are heavy deposits of the by-products of the decay process. This photomicrograph was taken using polarized bright field light microscopy which confirmed that the deposits were crystalline. Magnification: 110X.

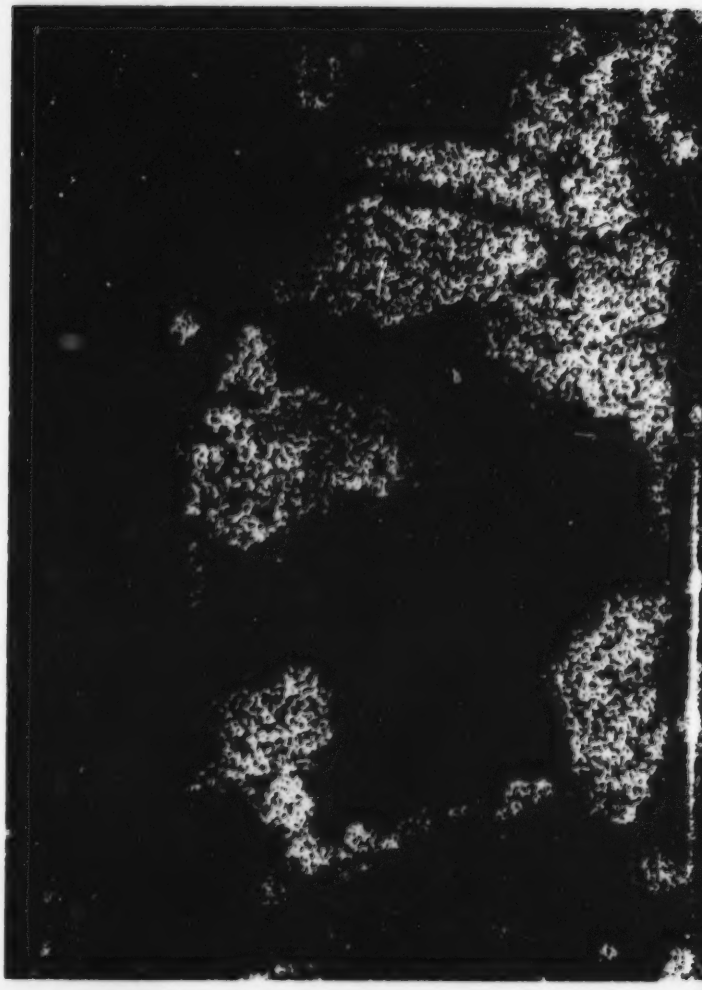


When the scanning electron microscope is used to examine an area similar to the one shown in the photomicrograph, the physical nature of the deposit that was discovered in this study becomes clearer. However, the chemical nature must be determined by other means. Magnification: 1500X.

The scanning electron microscope is recognized for the quality of its three-dimensional imagery of microscopic structures. This capability has been demonstrated in the large number of micrographs included in this publication. This instrument can also be employed for certain analytical applications one of which was used in this study: Energy Dispersive X-Ray Analysis (EDXA).

The spectrum displayed here was produced when the electron beam was concentrated on a cluster of crystals in the heavily attacked area of Disk 1-5-A. X-rays generated by interaction with this material resulted in two peaks that match exactly the characteristic energy levels indicated by the two l'ght vertical bars. These are identified as peaks for the element Calcium so it is assumed that the crystalline substance is a calcium salt.

To demonstrate another use of EDXA, this scanning electron micrograph of the cross-section of aspen attacked by *Fomes igniarius* was selected because of the large quantity of calcium salt deposits. The procedure used to provide graphic evidence for the distribution of such a material is known as elemental mapping.



Having produced the scanning electron micrograph and without disturbing the specimen within the microscope, an element map is prepared. Calcium x-rays are collected and recorded as small white dots. Areas of dot concentration can be seen to match the crystalline deposits in the micrograph thereby confirming the analysis for calcium.

Paper made from aspen pulp has a micro-structure that is fascinating. This scanning electron micrograph reproduced here at 150X shows that paper is a kind of reconstituted wood. The various types of cells can be recognized even though some of them may have been broken during processing. The long, slender fibers provide the matrix while the vessel elements, or parts of them, conform very well to the fibers. The cut edge of the sheet at the bottom of the photo suggests that it has a homogeneous, compact structure. Incidentally, most of the parenchyma cells have probably been lost as "fines."

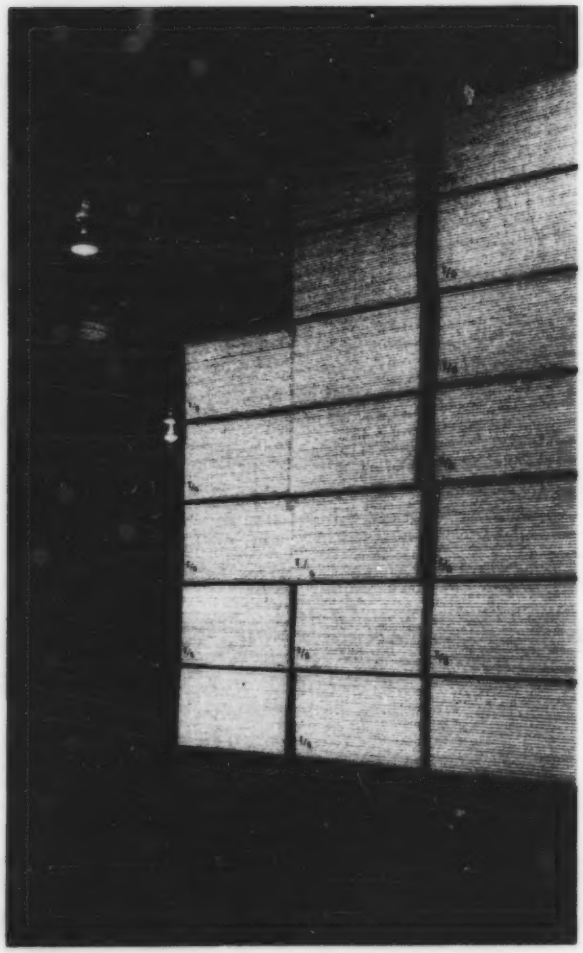
Reconstituted wood or composite wood is an ideal end-product for aspen. Two such examples shown here are aspen waferboard and aspen oriented strandboard. In these instances thin wafers or strands combined with a suitable adhesive are pressed into dense sheets having excellent physical properties. This type of product allows for the utilization of small trees or clear portions of larger trees.

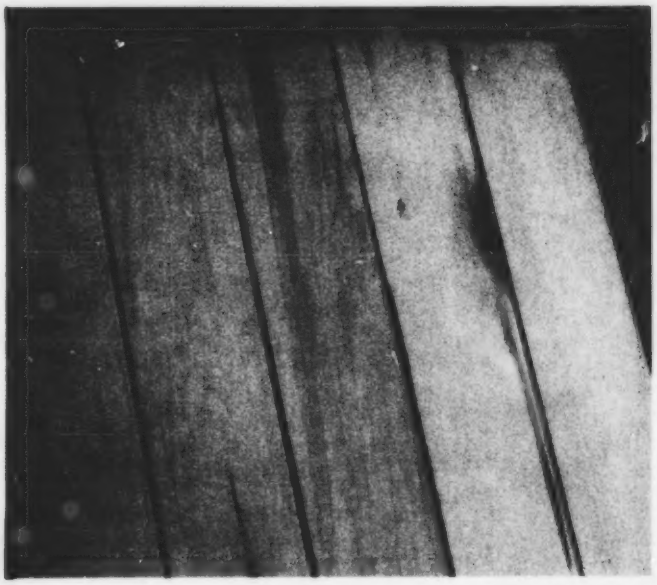
The Future for Aspen

In this case it is easy to predict what the future will bring since aspen is already being utilized very effectively in Alberta although not nearly as comprehensively as in Minnesota. The technology is well established for the manufacture of composite wood and new pulping techniques have demonstrated that papermaking with this species is feasible. Blending of aspen pulp with softwood fiber offers the possibility of controlling paper properties.

Many products currently manufactured from solid aspen can be improved using techniques that are in various stages of development. For example, aspen wood can be densified or dimensionally stabilized by treatments with penetrating resins that can be cured within the wood micro-structure. Fire retardancy can be imparted by impregnation with appropriate chemicals. Aspen can also be rendered more resistant to decay through processing with safe fungicides. All of these treatments are possible because of improved knowledge of the fine structure of aspen wood.

What can be done with the discolored and weakened aspen that was attacked by fungi? The evidence in this publication demonstrates that much wood substance remains and recent research confirms that this biomass is useful for conversion to products that are normally produced from petroleum. While the economics of an operation such as production of chemical feedstocks may not be advantageous in every situation, the technology exists. Improved utilization of aspen will depend on the design of integrated operations and the setting of priorities. Aspen is a valuable resource that should not remain underutilized while non-renewable materials at high market prices are exploited.





Other products made from aspen include lumber, furniture, and other items requiring large and clear pieces. With the development of new technology, the range of products can be expanded to include applications that demand fire and decay resistance, greater hardness and dimensional stability.

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DESIGN BY RON A. KARUS